A COMPREHENSIVE MANAGEMENT APPROACH TO MAXIMIZING UPS AVAILABILITY

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INTRODUCTION

For many years lead-acid batteries have been utilized in Uninterruptible Power Supply (UPS) duty, and as of today their reign does not appear to be ending. This paper explores (primarily) Valve Regulated Lead Acid (VRLA) batteries and strategies to increase their availability in this environment, but the techniques described are equally effective for larger Vented Lead Acid (VLA) batteries also. VRLA batteries are particularly well understood and their capacity degradation over time in controlled conditions has been explored and well documented (Kiel, Sauer, & Turpin, 2008).

Numerous technical advances have enabled directly measuring key indicative values from battery systems continuously and reliably (2, 14)These permanently installed solutions as *stationary instruments* are an essential building block to developing a formalized process whose primary goal was to maximize availability and the service life of UPS service VRLA batteries. All stationary instrumentation systems produce prodigious amounts of data, provide alarms for rapidly changing events, capture real time voltage levels during a discharge event and enable routine repeatable testing data.

This paper describes the core elements supporting a comprehensive process that leverages the full capabilities of these technological solutions, while preventing information overload of the end user and enabling remote analysts to efficiently manage the state of health of a large number of battery jars simultaneously.

STATIONARY INSTRUMENTS

Permanently-installed resistance, impedance and conductance measuring systems have continued to gain market acceptance, particularly over the last five years. This paper does not seek to dissuade the reader from an instrumentation approach, but that stationary instruments are a key element of the described process. Although battery voltage-type monitors may be installed for alarming, these systems do not provide an indication of battery health (9). These alarming systems were not considered suitable for increasing availability, while resistance and conductance methods do provide battery state of health data. Permanently installed battery management systems utilizing resistance or conductance metering have become a more popular supporting system, particularly in 30KVA and larger UPS systems.

One example for a moderately sized UPS configuration would be comprised of approximately 40 Jars of 12 Volt mono-block VRLA batteries in series, with each jar containing 6 cells. This class of UPS supporting configuration demands high discharge rate performance of 240 cells for every “UPS On-Battery” event. Due to the use of 12 Volt jars in this configuration, “metering points” only exist for one sixth of the cells. Consider that for such a large number of cells, coupled with the ability to only externally observe, the measurement task becomes more difficult.

For example, assume that one cell of a 12 Volt mono-block begins to fail and THAT cell’s resistance increases by 10%. The overall resistance as observed for that jar will only increase by 1.6%, presuming a worst case scenario of all other cells being completely normal and healthy.

Therefore, these high jar count and high cell count configurations demand the highest possible repeatability in instrumentation for resistance and conductance. Shown below is a sampling of instruments available to the marketplace. Note that resolution and accuracy for Stationary Systems are typically better than Portable Systems. Although not explored here, it could be argued that repeatability is more important than initial accuracy; repeatability is not a value that is easily represented in product specifications. In support of this effort and process development the ambient temperatures are always recorded, as are the negative post temperatures of all jars. If the environmental conditions have changed significantly, then the repeatability of the stationary instrument is considered part of the base errors.

Figure 1 Instrument Accuracy

Vendor	Range	Accuracy	Resolution
Portable Vendor 1	100-19,990 Siemens	+2% across test range	5 mV
Portable Vendor 2	0-xx µOhms	+/ 75 µOhms	6 mV
Stationary Vendor 3	0-32,000 µOhms	+/- 5 µOhms	4 mV

More than one third of the root cause evaluations of "UPS down units" is a direct result of battery failure (6). Several other factors have caused a change in the needs of Data Center customers that demand these systems.

First and foremost, the DC bus voltages of UPS systems in the range of 20KVA to 500KVA (6) are between 400 and 575 VDC. With more than 2000 injuries from Arc-Flash and 97% of technicians being shocked on the job in 2010, increasing worker safety continues to be a top priority in the electrical service industry and is mandated federally (CFR, 2010). Every worker exposed to these medium voltage DC systems represents personnel risks and vulnerability to the system itself (3). The time and costs to manually measure key performance values, like resistance, has become impractical more than a few times per year. Not unexpectedly, for UPS maintenance, many enterprises have switched to utilizing external experts, skilled, trained and equipped for manually servicing medium voltage battery strings.

Figure 2 (8) Induced Outages

$$\text{PM Safety} = 1 - \left[\frac{\text{Number of CE caused outages}}{\text{Number of PM visits}}\right]$$

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Another primary shift to stationary instruments has been caused by the enhanced repeatability of permanently installed instruments (14). The basic construct and philosophy of stationary instrumentation systems is based upon establishing an initial baseline value, particularly for resistance or conductance. This baseline is then examined repeatedly at regular intervals, ranging from once a week to one time a month. Portable instruments are certainly capable of repeatable, reliable readings; but several elements of potential error are eliminated with a stationary system, namely: instrument calibration, measurement points, connections, and lead variation errors.

Stationary instruments are capable of storing data internally and are "on the job" continuously to capture alarms, events and measure the batteries during a discharge, eliminating the requirement to install a separate voltage alarm system. This database is available during forensic analysis and performance analysis. However, key to maintaining availability is the long term and continuous storage of data trends of the resistance or conductance of the battery jars (by jar). Storing and graphically presenting data concerning the comprehensive state of operation and state of health of the battery strings are the primary value offerings provided to the UPS operator.

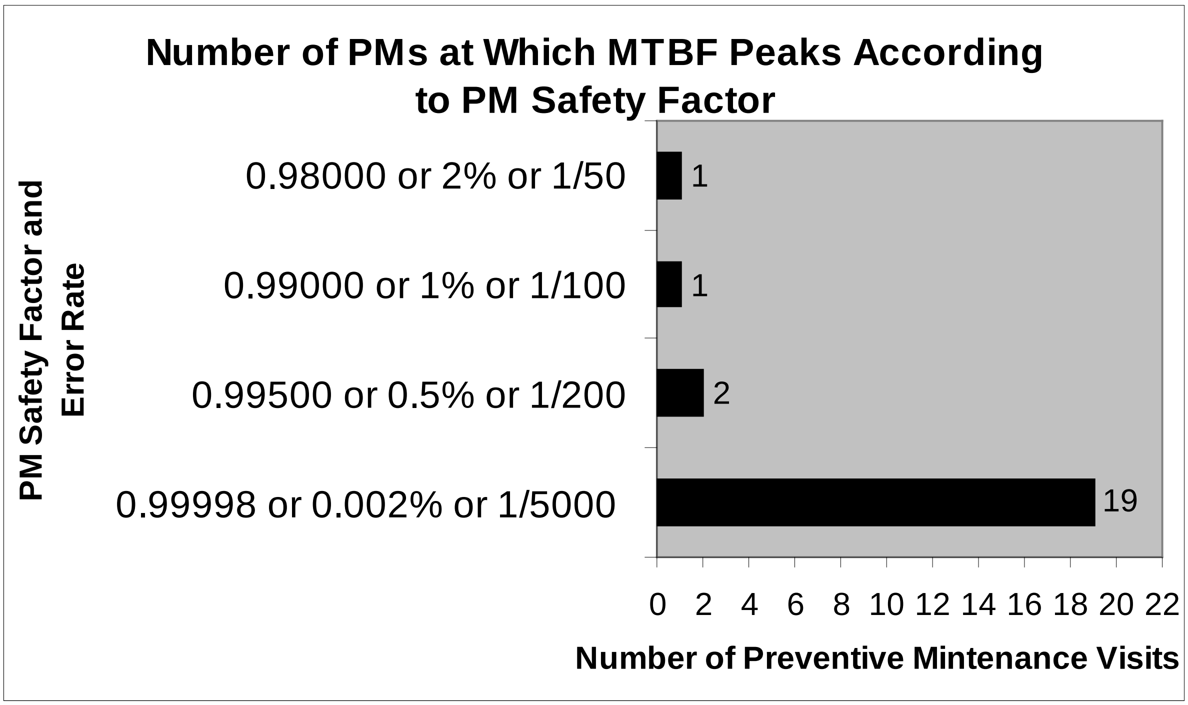
OPERATORS

Much has been written concerning the centralization and consolidation of data centers (13). A consolidation of expertise has occurred also. Personally participating in many battery service events during late 2010, my observation is that the operators have a great many additional responsibilities and the battery subsystem and its welfare is often entirely managed by their trusted service providers. While some data centers are experiencing runaway growth, others are being impacted by economic conditions, often postponing critical infrastructure service (like UPS batteries). These operators demand both immediate notifications of events and access to state of health data in partnership with their service provider, and desire higher level summaries, with more supporting data. The day may have passed where on the recommendation of a service provider a battery string is replaced.

SERVICE PARTNERS

The classic role for a service partner has been to safely provide preventive maintenance inspections and measurements in person to the battery system. From visual inspections, to torque measurements, to hydrometer readings, an expert visited the batteries and deemed them healthy or they have pointed out any observed deficiencies directly to the operator. Interpreting these deficiencies was handled between the service partner and the operator. In most cases the service partner's role does not extend to utilizing stationary data on site, the stationary instrument or confirming its calibration.

Figure 3 (8)

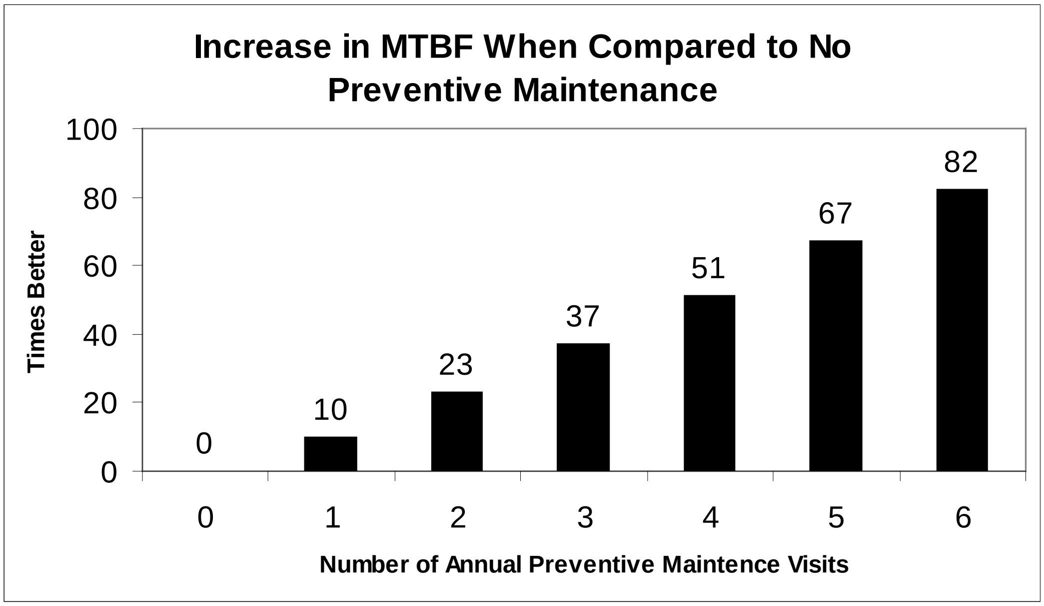


Technology solutions may never negate the need for frequent, in person examination of battery systems. Today these systems serve to improve the capabilities of the service technician. Often these systems point directly to a jar that upon further inspection has an issue or impending failure. Remembering that Mean Time Between Failures (MTBF) is the statistical likelihood of a failure (see Figure 4). An extensive analysis of 185 million operating hours conducted for medium voltage UPS use indicates that MTBF increases by a factor of 10 for a single annual visit, by 51 times for quarterly preventive maintenance and 82 times for 8 week preventative maintenance, see Figure 5. (3), over break-fix service paradigms.

Figure 4 (8)

$$\text{MTBF} = \frac{\text{cumulative operating hours}}{\text{number of outages} + 1}$$

Figure 5 (8) Increase In MTBF



TRANSPORTING DATA

The increase in sheer volume of produced data and base alarm levels produced has demanded that network transports be utilized for all battery telemetry, alarms, real-time events and stationary instrument testing. There are several methods utilized today, with reverse VPN being the most secure and protocol neutral methodology (12), for Ethernet transportation.

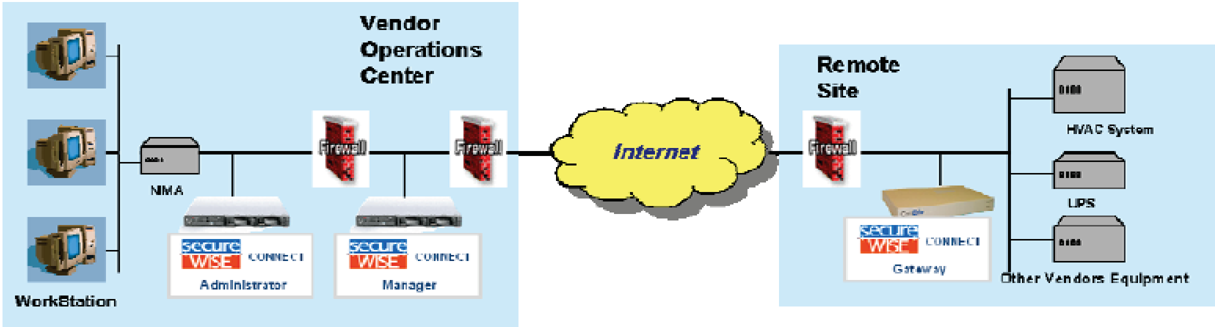
Service partners that require remote access to an enterprise system behind firewalls will occasionally implement either a hardware or software Virtual Private Network (VPN) connection from the enterprise to the service partner's network. These dedicated connections, known as site to site VPN connections, require IT resources of both organizations to set up and establish fixed endpoints on the internet to create an information tunnel between the businesses. Often the enterprise limits the direct connection permissions in an IP address "white list", the list of addresses that the service partner can address. Software based permanent VPNs operate identically, but are established in router and server hardware directly. Several tutorials exist which indicate this dedicated usage methodology (11).

Other Enterprises will allow their Service Partners to install their VPN client software on the Partner's computers to gain access to the network and therefore the devices. These are known as remote access VPNs (5). This connectivity keeps access control directly in the Enterprise's hands, but requires individual accounts for each remote user. The resultant chaos for the service partner includes many logins and passwords for the enterprises they serve.

Furthermore, no Machine to Machine (M2M) connectivity exists, requiring manual interaction with the remote system. Hybrid systems have been developed that push data out over conventional methods. These hybrid approaches range from email to web-based systems. These are effective output only systems and tend to be dedicated purpose constructs. Relying on email to transport alarm telemetry places the enterprise at the vulnerability of an often over used resource in both businesses.

An effective data transport methodology is an automated dynamic VPN based system. These systems create an on-demand M2M connection from the remote system for alarms, system events and routine data transport. These secure, encrypted methods utilize well accepted Secure Socket Layer (SSL) connections that have been employed throughout the internet for secure consumer transactions with web sites. One example dynamic VPN solution is detailed below. These operate much like a software VPN installed on many laptops. A dynamic VPN allows for scalability, but also allows both the enterprise and the service partner to transparently manage access for the two businesses, not one device to one person (7).

Figure 6 A Common Dynamic VPN Architecture



ENABLING REMOTE ANALYSIS

These Technical innovations that have enabled wholesale data transmission have enabled an additional role, namely the analysis engineer. In this role the entire historical lifespan of the battery jar is analyzed and compared both against its nearby family and its extended family (the entire portfolio for that battery model) over time. The graphical presentation and portfolio data afforded to these specialized engineers allows extensive leverage of their skills. For example, one analyst can patrol 500-1000 battery strings. In examining a "day in the life" of an analyst I have found that for any particular day the analyst takes an overview examination of 20-40 battery strings consisting of 40-240 Jars, with VRLA type jars demanding the most attention. From these overview analyses, an in depth look is taken at one or two strings resulting in a final analyst's recommendation. This recommendation is conducted in consultation with the field engineering staff directly, resulting in a final state of health determination for the jar and string.

RESULTS

This unique three party relationship between the operator, field engineer and analysis engineer has resulted in absolute uptime and availability for UPS battery strings since 2006, with hundreds of millions of hours of runtime. There are several key elements of this business intelligence based approach that resulted in such high availability.

First, the economic defense of properly maintaining a particular string is immediately rewarded through frequent and repeatable testing with jars that need additional examination. When a failing battery jar is detected (pre or post warranty), a detailed history of received telemetry is available, including the three key elements of temperature, voltage and resistance over the lifecycle of a particular battery jar. Rogues are detected accurately and early.

The "defense" and evidentiary case to expeditiously remove a defective jar is easily made; the data virtually eliminates any "wait and see" dialog with the operator's finance department.
Second, the supporting on-site maintenance keeps watch over the slow moving and less detectable issues that can occur occasionally. For example, a leaking post seal will ultimately be detected by the stationary instrument as high resistance due to dry out, but an on-site inspection will observe this long before sufficient electrolyte loss has affected resistance. Again, a well defended case of a physical observation that is not disputable removes any questions as to the correct course of action.

Finally, the detailed voltage events are recorded and displayed to the operator upon demand. Seeing how the battery string has actually performed during a discharge event absolutely and conclusively confirms the energy delivery from each and every jar in every string of the battery system.

Tying these three elements together in both local graphical real-time and graphical report formats for the operator and field engineer allow more rapid detection and ultimately drives corrective action based decision making to quickly replace defective jars from battery strings.

CONCLUSION

There will always be a grey area between perfectly suitable and barely suitable battery performance. Technological advances in recent years have greatly reduced the relative width of this grey area. Advances in processes and methodology have demonstrably decreased it further. Figure 7 below, details that the top two uses for remote telemetry by best in class businesses are condition and performance (1). Coupled with on-site experts the availability increases have allowed battery availability to be increased dramatically. The resultant benefit has been increased availability and ultimately real dollar savings in operational uptime for critical facilities operators. As the technical solutions have been delivered to operators, the ability to add additional, remote expertise that is greatly leveraged by the technology allows a breakthrough in service capabilities that were previously out of reach for all but the largest enterprises.

Figure 7 Remote Connectivity Uses

Aberdeen Insights — Use of Remote Connectivity

Table 4: Leading Uses of Remotely Captured Data for Best-in-Class firms

Current Use	Percent of BIC that Remotely Capture Data	Planned Use	Percent of BIC that Remotely Capture Data
To monitor asset condition	78%	To forecast future failures and plan service resource needs	58%
To monitor asset performance and quality to assist in preventive maintenance	61%	To improve design of product	44%
To inform field technicians of failure and recommend resolution scenarios prior to dispatch	50%	To determine value-added services	39%
To monitor asset usage information for repair/replacement decisions	50%	To execute repair over a network without technician dispatch	28%
To determine value-added services	44%	To ensure timely/accurate invoicing or billing	28%
To execute repair over a network without technician dispatch	39%	To determine root cause of failure for warranty claims	28%

Source: Aberdeen Group,

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